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Volatiles in Skin of Low Dose Irradiated Fresh Chicken

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ABSTRACT

Fresh chickens were irradiated with up to 1200 krad at 0–5°C. Volatile compounds from the skin and subcutaneous fat of these chickens, and from unirradiated controls, were analyzed by gas chromatography. Acceptability of the odor of the chickens was also evaluated. Other samples (0 and 300 krad) were evaluated by chemical and sensory analysis after storage at 4°C. Analysis of volatiles indicated that levels of octane, 1-octene, hexanal, and nonane increased regularly with radiation dose. Amount of total volatiles was greater in unstored irradiated samples than in controls, but this was reversed after storage. After 14 days, the irradiated sample still had acceptable odor, while the control ahd severely deteriorated.

INTRODUCTION

RESEARCH ON FOOD IRRADIATION has spanned many years, investigating chemical and physical changes along with resulting effects on safety, nutritional quality and acceptability (Josephson, 1983; Josephson and Peterson, 1982). Exposure levels in the 10–20 krad range inhibit the sprouting of potatoes, onions, and other root crops. Levels of 25–100 krad delay ripening of soft fruits, mushrooms and other perishables and destroy parasites and insects in meat, cereals and soft fruits. These applications have recently been approved by the U.S. FDA (1986). Higher doses, up to 1 Mrad, destroy dangerous bacteria such as Salmonella in poultry, also prolonging refrigerated shelf life. Foods irradiated at 1 Mrad to 5 Mrad can be completely sterilized for long term storage at room temperature.

The use of low doses of ionizing radiation to reduce the number of Salmonella and extend shelf life of refrigerated poultry has been investigated previously. Radiation doses of 200–400 krad effectively destroy all Salmonella present in chicken carcasses (Kahan and Howker, 1978; Mossel, 1977). Fresh chicken treated with a 200 krad dose and stored at 1.6°C had a total plate count after 21 days equivalent to that of fresh killed chicken (Kahan and Howker, 1978).

An undesirable consequence of food irradiation is the development of off-odors and flavors and discoloration. The amounts of undesirable components produced are a function of radiation dose and temperature (Merritt et al., 1975). Levels are decreased by irradiation of subfreezing temperature, but freezing produces other changes, especially in texture, unacceptable in fresh chicken. In meat sterilized at subfreezing temperature, volatile compounds were found to be predominantly hydrocarbons, sulfur compounds, and certain alcohol and carbonyl compounds (Merritt, 1972; Merritt et al., 1975). These volatile compounds were the same for chicken, pork, beef and other meats and did not vary in type but only in intensity. Hydrocarbons and oxygenated compounds are formed predominantly from lipid and the sulfur compounds from protein. For chicken irradiated at 5–10°C, there is a threshold dose of about 250 krad, below which a taste panel can not detect changes in flavor (Kahan and Howker, 1978; Sundarmadji and Urbain, 1972). Doses above this produce a characteristic irradiation odor that dissipates after a few days' storage. A chicken odor then predominates. In contrast, the odor of nonirradiated chicken deteriorates from a fresh chicken odor to a putrid odor during similar storage.

From the point of view of safety, long term studies in two rodent species, a three generation reproduction study in rodents, and a one year study in dogs have failed to reveal any significant adverse findings associated with the ingestion of irradiation sterilized chicken (Thayer, 1984). If the compounds formed at low dose are, in fact, similar to those in the sterilized chicken, the chemical safety risks should also be similar.

The objectives of this study were to investigate the chemical changes in fresh chicken at doses sufficient for pathogen destruction and to relate these with off odors. Previous chemical studies examined changes in frozen chicken at sterilizing doses, while low dose studies have focused on microbiological and sensory changes. Specifically, the objectives were to: (1) identify volatile compounds which occur as a reuslt of low dose irradiation of fresh chicken, (2) investigate the relationship between volatile compounds and off odors and (3) investigate the change in volatiles during storage of irradiated and control chickens.

MATERIALS & METHODS

Chickens

Fresh chickens were obtained from a local poultry supplier (Spring Poultry Co., Springhouse, PA or Victor Weaver Inc., New Holland, PA) directly after slaughter and cleaning and placed on ice for transportation to the irradiator.

Irradiation

Chickens were exposed to cesium-137 gamma radiation from a CsCl source described by Shieh et al. (1985). The irradiation rate was 10 krad/min. During irradiation, crushed ice and chilled water were used to control sample temperature between 0° and 5°C. Those samples listed as nonirradiated controls were kept on ice. For the dose study, four quartered chickens were reassembled, one quarter from each chicken, to minimize sample variation. The four reassembled chickens were packed into separate food grade plastic bags and irradiated at doses of 0, 300, 600 and 1200 krad (0, 3, 6 and 12 kGy). For the storage study, three chickens were halved. One half of each chicken was irradiated to 300 krad, the other half was nonirradiated control. These samples were stored at 4°C and evaluated after 0, 7 or 14 days.

Volatiles collection

After irradiation, chicken samples were kept on ice until volatiles collection, still on the same day as slaughter. Skin and attached fat were removed from the body of the chickens and chopped with a knife. A portion of about 20g was ground with a mortar and pestle along with an equal weight of anhydrous sodium sulfate. Volatiles were trapped in a 10 cm long × 3.2 mm i.d. × 1/4 in (6.35 mm) o.d. stainless steel tube packed with about 0.15 g Tenax-GC (20/35 mesh), using a procedure similar to that used by Galt and MacLeod (1984) for sampling cooked beef aroma. A flask containing the ground sample was connected to one end of the Tenax trap, and the other end led to a dry ice trap and a rotary vacuum pump. The system was held at a pressure of about 50 mtorr. Organic volatiles adsorbed onto

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the Tenax particles, while water not held by the sodium sulfate passed through to the dry ice condenser; nonvolatiles remained in the flask. Collection continued for 4 hr. This time period was based on the absence of detectable odor or visible water in the sample flask, attainment of constant weight of the flask and no further increase in recovered volatiles with increased collection time.

Volatiles analysis

The contents of the Tenax trap were analyzed by gas chromatography (GC) on a Shimadzu GC-9A instrument using a flame ionization detector (FID) with nitrogen as carrier gas at 30 mL/min. The Tenax trap was heated at 240°C for 20 min with carrier flow. Desorbed volatiles were carried to a loop of 1/16 in o.d. × 0.03 in i.d. (1.59 mm o.d. × 0.76 mm i.d.) tubing, where they were condensed in a dry ice/acetone bath. At the end of 20 min, the dry ice trap was removed and the loop heated for 12 min with a heat gun to vaporize sample volatiles, which were carried to the GC column. The oven was at 40°C for 5 min, increased at 5°/min to 150°C, then 10°/min to 200°C and held at 200°C for 5 min. The column was 6 ft x 1/8 inch o.d. (1.8 m x 3.2 mm o.d.) x 2.1 mm i.d. stainless steel packed with 3% OV-17 (® Ohio Valley Specialty Chemical Co.) on Chromasorb WHP 100/120 (Alltech Assoc., Deerfield, IL).

Volatiles identification

For peak identification by mass spectrometry (MS), the contents of the Tenax trap were eluted with hexane. The hexane solution was concentrated under a stream of air, then analyzed on a Hewlett Packard 5995 GC-MS. The column was 12 m × 0.2 mm i.d. fused silica coated with a 0.33 μm film of crosslinked methyl silicone. Carrier gas was helium at 1.5 mL/min. The oven was isothermal at 40°C for 5 min, then increased at 5°/min to 200°C.

Odor evaluation

Before skin removal, chickens were evaluated by a panel of nine (storage study) or ten (dose study) people, who rated odor on a 5-point scale, with 1 meaning very unacceptable, 3 meaning neutral and 5 meaning very acceptable. Off-odor identities were also noted.

RESULTS & DISCUSSION

IN COMPARING GC-FID chromatograms from the chickens irradiated at different doses, increasing dose caused an overall increase in the amounts of volatile material. Only a few peaks, however, increased regularly with dose. Variations in other peaks were minor, and perhaps due to sample variation not eliminated by our mixing procedure. There were linear increases in peak heights only for the peaks with retention times (RT) of 2.5 min, 4.8 min, 9.2 min and 11.8 min, as shown in Fig. 1. Regression analysis indicated positive slopes and correlation coefficients ($p<0.05$) for all four compounds. GC – MS analysis identified these as octane, 1-octene, hexanal and nonane, respectively. These have all been found in cooked chicken in previous work (Ramaswamy and Richards, 1982). These volatiles are also found in both cooked and irradiated beef (Merritt, 1972). Previous studies of irradiated chicken (Freeman et al., 1976; Merritt et al., 1985) identified a number of compounds, including octane and octene. We did not attempt identification of every peak in the irradiated samples, but all were apparently also present in the nonirradiated control. This is in general agreement with previous work (Merritt et al., 1975), which found that qualitatively the same volatiles occurred in both irradiated and control meat but that larger quantities were released from irradiated specimens.

Increasing radiation dose caused a decrease ($p<0.01$) in odor acceptability (Table 1). While all irradiated samples were rated lower than the control, only the highest dose, 1200 krad, received lower than the neutral rating of 3. Most of the panel were familiar with and able to identify, irradiation odor. Since the compounds identified can be formed by decomposition of fatty acid hydroperoxides, exclusion of oxygen during irradiation may inhibit their formation. This might also help decrease the irradiation off-odor of irradiated chicken, although we could not conclude that the off-odor was caused by these specific compounds.

The unstored 300 krad irradiated half chicken (Fig. 2, bottom) gave more volatiles than its nonirradiated control (Fig. 2, top), as in the dose study. Again, only a few peaks were markedly larger in the irradiated sample. These were assumed to be the same as those identified in the dose study, based on retention times. There was also a slight irradiation odor in the unstored 300 krad treated chickens (Table 2), as in the dose study. Similar differences in volatiles were observed between irradiated and nonirradiated chicken halves stored for 7 days, though the differences were less. The irradiated sample stored 7 days had a more acceptable odor than either its nonirradiated control or the unstored irradiated sample (Table 2). In the samples stored for 14 days, the nonirradiated half had a greatly increased level of volatiles (Fig. 3, top) compared to the irradiated half (Fig. 3, bottom). The irradiated sample stored for 14 days still had an odor about as acceptable as fresh chicken but its nonirradiated control was very unacceptable (Table 2). Both the increase in volatiles and the decrease in acceptability of the nonirradiated sample were almost certainly due to microbial growth. While microbe levels were not determined, previous studies on irradiated and control chicken (Freeman et al., 1976; Kahan and Howker, 1978) support this assumption. Microbial studies of this type of product are necessary, as there is concern that selective destruction of microorganisms would allow growth of pathogens without typical signs of food spoilage (FDA, 1986).

Since the three storage times used different chickens, sample variation may somewhat confound comparisons among times. Still, only small differences in amounts of volatiles were seen

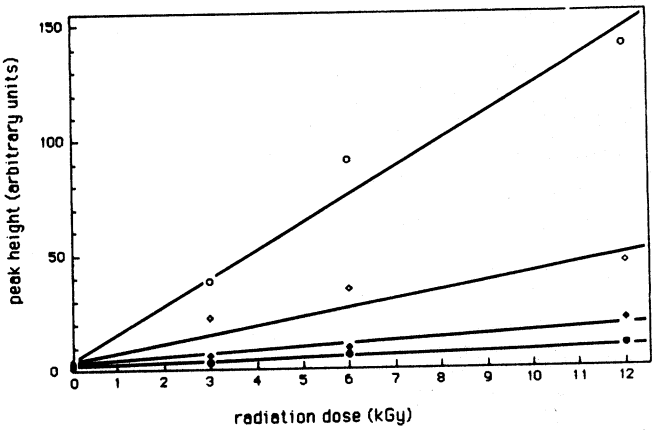

Fig. 1—Increases in volatile compounds with irradiation dose: ●, octane (RT = 2.5 min); ♦, 1-octene (RT = 4.8 min); ◇, hexanal (RT = 9.2 min); ○, nonane (RT = 11.8 min).

Table 1—Odor evaluation scores from dose study

Dose (krad)	Score[a]
0	4.80 ± 0.42[b]
300	3.60 ± 0.52[c]
600	3.10 ± 0.57[d]
1200	2.90 ± 0.74[d]

[a] Mean ± standard deviation (n = 10); 1 = very unacceptable, 5 = very acceptable.
[b-d] Pairs followed by the same letter are not significantly different ($p>0.05$).

Table 2—Odor evaluation scores from storage study

Storage (days)	Dose (krad)	Score[a]
0	0	4.56 ± 0.73[b]
0	300	3.22 ± 0.83[c]
7	0	3.33 ± 0.71[c]
7	300	4.44 ± 0.73[b]
14	0	1.56 ± 0.73[d]
14	300	4.22 ± 0.67[b]

[a] Mean ± standard deviation (n = 9); 1 = very unacceptable, 5 = very acceptable.
[b-d] Pairs followed by the same letter are not significantly different ($p>0.05$).

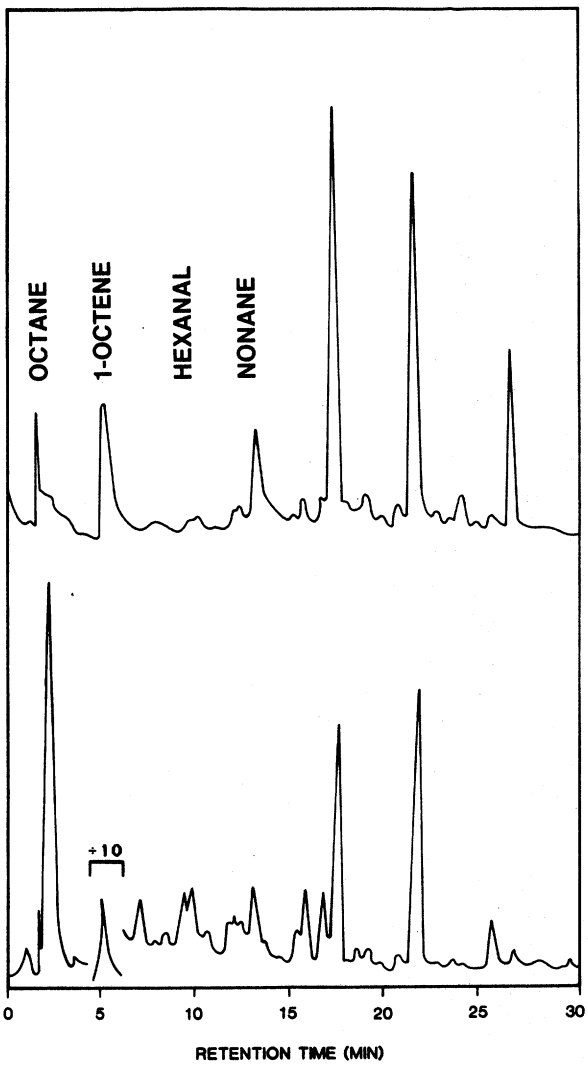

Fig. 2—GC-FID of unstored chickens. top: unirradiated, bottom: 300 krad.

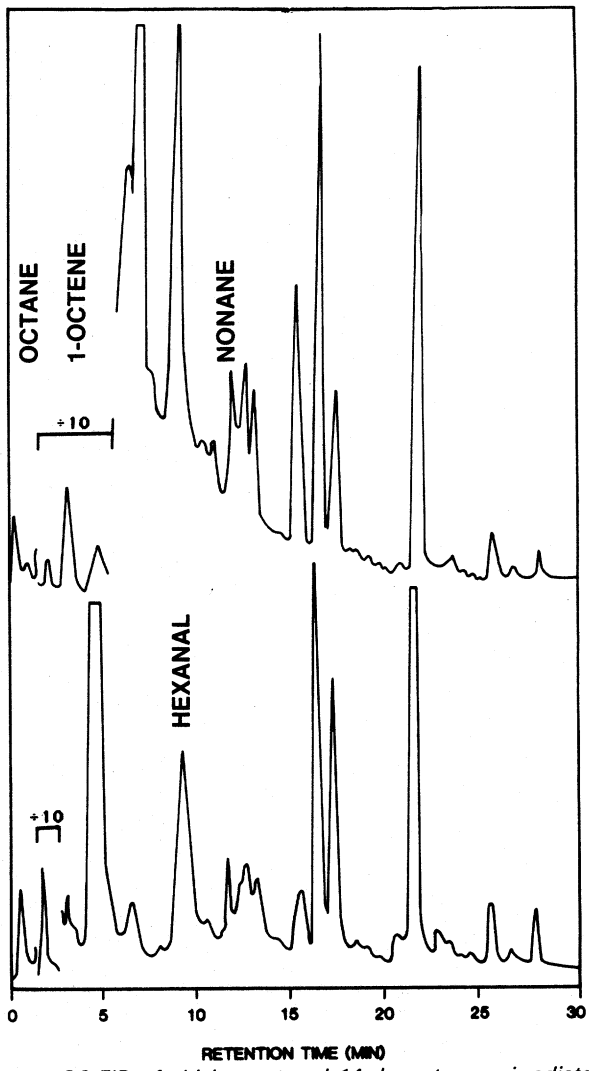

Fig. 3—GC-FID of chickens stored 14 days. top: unirradiated, bottom: 300 krad.

when the irradiated half chickens stored for 0, 7, and 14 days were compared with each other or with the 300 krad sample from the dose study. Some volatiles were found apparently in nonirradiated chickens stored for 7 days and 14 days, not seen in fresh chicken nor in irradiated chicken. Irradiated samples stored 7 and 14 days were rated almost as high as fresh nonirradiated chicken, suggesting dissipation of the irradiation odor and lack of microbial spoilage. Analysis of variance of the odor evaluation scores indicated a significant contribution to total variability both from irradiation and from storage and also from the interaction of these two effects.

In summary, the relationship among irradiation, storage, volatiles, and odor was complex. Treatment of fresh chicken with 300 krad allowed an acceptable product after extended refrigerated storage. Volatile compounds identified in irradiated samples were not uniquely products of irradiation.

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Ms received 12/15/86; revised 3/28/87; accepted 4/17/87.